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MATING BEHAVIOUR OF *MONISTRIA CONCINNA* (ORTHOPTERA: PYRGOMORPHIDAE) AND *HEIDE AMICULI* (ORTHOPTERA: EUMASTACIDAE) FROM AUSTRALIA WITH NOTES ON THEIR FEEDING BEHAVIOUR

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Abstract

The mating behaviour of a representative species of the endemic Australian Monistriini tribe and Morabinae subfamily is described for the first time. Pair formation and courtship of these flightless species are simple, consisting of stalking and antennal pointing by males and, for the morabine, antennal tapping of the female by the male after he mounts her. Brief notes on food plants and feeding behaviour are included.

Introduction

Monistriine grasshoppers form an endemic Australian tribe of the Pyrgomorphidae, consisting of 4 genera and 12 species (Key 1985). They are robust, usually brachypterous insects with aposematic coloration. These insects feed on perennial forbs and shrubs and occur throughout much of Australia in habitats ranging from the arid centre to subhumid areas and cold mountain regions (Key 1985). Their population density has been quite variable, ranging from high numbers causing defoliation (Allsopp 1977a, 1977b, Key 1985) to infrequently encountered and fragmentally distributed races of species in mountains of southeastern Australia (Key 1985). Biological information on the Monistriini is sparse, consisting primarily of a recent monograph (Key 1985 and earlier taxonomic and cytogenetic references therein) and a few studies on food plants, natural enemies, and seasonal development (Allsopp 1977a, 1977b, 1978, 1979; Green 1983). There are no references to the mating behaviour of species of Monistriini in the literature.

Morabine grasshoppers are an endemic Australian subfamily of the Eumastacidae that consists of 41 described genera and about 250 species (Key 1976, 1977, 1982). They are attenuate, apterous insects with ensiform antennae. Most morabines occur and feed on forbs (broad-leaf herbs) and shrubs although about 20% inhabit grasslands (Key 1974). They are generally polyphagous but their low vagility and, in many cases, restricted habitats, can result in a very limited choice of food (Blackith and Blackith 1966) and may account in part for their low populations. Morabine species from different genera are commonly sympatric and have apparently evolved isolating mechanisms that include specific ecological niches and parapatry. Intraspecific variability also occurs and chromosomal polymorphism and chromosomal races may be particularly characteristic (Key 1974). Studies have been made on the anatomy, physiology, development, genetics, and taxonomy of morabines (cf. references in Key 1976), but no information on their mating behaviour has appeared in the literature.

The purpose of this study was to describe the mating behaviour of a representative grasshopper species in the Monistriini and one in the Morabinae. *Monistria concinna* (Walker) (montane race), a monistriine of the low mountains of south-eastern Australia, and *Heide amiculi* (Sjöstedt), a morabine of New South Wales coastal and subcoastal heath, were selected.

Methods and Materials

M. concinna individuals were collected 10 January 1989 at Piccadilly Circus and Mt. Ginini) summit in the Brindabella Range in the Australian Capital Territory. They occurred sporadically) in open meadows of forbs and grasses. Individuals were maintained on *Plantago lanceolata* L. (English plantain) in the laboratory with an occasional addition of *Taraxacum officinale* Weber ex Wiggers (dandelion). These foods allowed third instar nymphs to develop to adults and adult males to live for over 4 months. The observation cage was a 30 x 30 x 20 cm-high glass terrarium with a wooden top containing a central screen over which was placed a 40 watt incandescent bulb to produce a temperature averaging 27°C on the cage floor. Sandy loam and vegetation formed the cage floor and the photophase ranged from 13 to 14.5 h. Behavioural descriptions are a composite of 3 females and 5 males.

H. amiculi was collected 19 January and 8 March 1989, from coastal heath 2 km NE of the village of Jervis Bay, New South Wales. Individuals were fed *Correa* cv. *Mannii* (Myrtaceae), a widely grown ornamental shrub, which was sufficiently nutritious to allow the development of a last instar to the adult stage, oviposition, and longevity for over 3 months. Grasshoppers were kept in an 18 x 18 x 35 cm-high glass terrarium with a screen top. The cage had a 10 cm-wide vertical strip of screening in the centre for climbing, a sand floor, and stems of vegetation resembling the habitat. An overhead 40 watt incandescent bulb provided light and a temperature averaging 30°C at the vertical midpoint of the cage. Natural lighting was present and the photophase ranged from ca. 11 to 14.5 h. Behavioural descriptions are a composite of observations on 4 females and 2 males.

Results and Discussion

Monistria concinna

Feeding Behaviour

Two specimens were captured on *Podolepis robusta* (Maiden et Betche) J.H. Willis (Compositae) and fed on this plant for several days before it was replaced with the more readily available laboratory diet. As a grasshopper approached a food plant, it lowered its antennae to touch the leaf and often moved the bent apical fourth of the antennae across the surface in a posterior direction four to five times, each pass taking ca. 1 s.

Mating Behaviour

Pair Formation - Monistriini lack tympana (Key 1985) and have not been reported to stridulate. *M. concinna* males apparently use vision to locate and approach females. Before moving toward the female, the male's antennae are usually lowered from a raised, spread position to a parallel, stationary position and pointed toward the female. This antenna orientation is common to many acridids although *M. concinna* did not vibrate its antennae as many do (Uvarov 1977). If the visual sense is the dominating pair formation stimulus, then pointing the parallel antennae toward a female and holding them stationary in this confined airspace may reduce spurious olfactory and tactile (e.g., wind) sensory input as well as expose a smaller surface area to these stimuli, thus allowing visual cues from the female to be received with less signal interference.

Males approached females by slowly stalking, walking quickly, or making a short jump, generally approaching laterally until about 8 cm away. Stalking lasted up to 3 min and the time period between the cessation of stalking and mounting a female ranged from 10 to 45 s (n = 9). A female either remained motionless, moved away or, less commonly, raised her hind femora slightly to resist a male.

Mounting, Courtship and Copulation - Females rarely jumped or kicked when mounted. After mounting, the male faced anteriorly, rotating and vibrating its antennae for 8 to 12 s up to 5 times. Generally the vibrating antennae did not contact the female. Some males vibrated one or both hind femora intermittently (ca. 10 cycles/s, 4 to 16 cycles/episode) which occasionally resulted in the tarsi vibrating against the female's abdominal terga. Females rarely vibrated their hind femora. If the female began walking the male would start femora vibration again which usually caused her to stop. Males occasionally rocked from side to side for ca. 2 s, repeating this movement several times which sometimes caused the female to rock weakly in response. Some males palpated the female's nota near the base of the wings; this occurred whether she was motionless or moving. A female generally moved her head and prothorax slightly up and down for several seconds on an irregular basis until copulation. The time from mounting to copulation ranged from 2.5 to 8 min (n = 11). Pick-a-back riding (Key 1985) where the non-copulating male is carried by the female was observed at times.

Aggression - During copulation there often were no aggressive signals between the copulating male and an approaching or contacting male. However, the female sometimes moved her head and thorax up and down several times in succession, each series lasting ca. 3 s. These movements were identical to the body movement described above during the male's attempt to copulate and may be a disturbance response.

On one occasion a second male mounted a copulating pair, orienting himself on the opposite side of the female from the first male (who had moved to one side). The second male vibrated his antennae and femora with only slight femoral response from the first male. Then the first male kicked out and the second male jumped off. The first male repositioned himself dorsally and displayed generalized disturbance reactions which consisted of slowly raising and lowering his hind femora and alternating his tibia from a folded to an extended position. His antennae also vibrated for ca. 1 min during this time. On another occasion a second male dislodged the first male, and when the latter attempted to remount the female the newly mounted male raised his hind femora three times with the tibiae extended about 45° from the femoral axis. Femora raising and tibia extension are common disturbance or male rejection signals (Otte 1970).

If a male approached within a few millimetres of, or mounted, another male, the latter responded with a rapid vibration of his antennae and one or both femora and then moved away. The aggressor male frequently vibrated his femora as well after dismounting.

Pyrgomorph species in other tribes show mating behaviour that is similar to *M. concinna* (Srivastava 1957, Fishelson 1960). Srivastava (1957) noted that the newly mounted male *Atractomorpha crenulata* (F.) (Atractomorphini) repeatedly pats the pronotum and head of the female with his forelegs and antennae, an action not observed with *M. concinna*. Also, the female resisted mounted males more vigorously than *M. concinna* which could be a reason why more male courtship was required for successful copulation.

Female stalking without courtship display, and antenna vibration and hindleg shaking or vibration as found with *M. concinna* males is widespread among non-acoustic acridid species in the melanopline subfamily of North America (Otte 1970) and five subfamilies of South America (Riede 1987). Many of these species vibrate femora more persistently than *M. concinna* males and a few have colored tips on their antennae or knees (Riede 1987). Hindleg vibration, especially where the substrate is contacted, is thought to play an important communication role in vegetation-inhabiting species.

Heide amiculi

An average of only one grasshopper per 2 h was collected due to their cryptic gray coloration, slender silhouette, unobtrusive behaviour, and assumed low population. Individuals occurred up to ca. 0.5 m on various xerophilous low plants.

Feeding Behaviour

Nine forbs and shrubs, two grasses and one sedge were collected from the habitat for feeding trials, of which the foliage of four species was placed in a container of water and presented to grasshoppers for 24 h. *H. amiculi* fed only on the shrub *Leptospermum scoparium* Forst. f. var. *rotundifolium* Maiden & Betche (Myrtaceae). The grasshopper approached the leaf and tapped it two or three times with its antennae in very rapid succession (occasionally repeating the tapping sequence) before contacting the leaf with its mouthparts and beginning to feed. While an individual was eating this species or the maintenance species, *C.* cv. *Mannii*, a blade of *Poa* grass from a lawn could be placed on top of the shrub leaf, the latter carefully withdrawn, and the latter would continue to feed on the grass blade. However, the *Poa* sp. alone initiated only limited feeding.

Some morabines may be facultative nocturnal feeders (D.C.F. Rentz pers. comm.). To test this hypothesis with *H. amiculi*, two individuals were starved for 18 h and then each placed in a 7 cm diameter Petri dish with a leaf of *C.* cv. *Mannii*. One dish was covered with black plastic (complete darkness) and the other with plastic perforated with pinholes (subdued light) ca. 1 mm in diameter and at a density of 20 per 40 cm^2. After 4 h, grasshoppers in complete darkness had not fed but those in subdued natural light had. If the dish was covered with unperforated or perforated black plastic while the individual was feeding, ingestion stopped in darkness but continued in subdued light. These results suggest that in nature some feeding may occur under low light conditions (dusk, moonlight).

When the large cage of grasshoppers was placed in complete darkness for 18 h, the grasshoppers usually moved to other locations to roost soon after being placed in the dark. When light was restored all were eating within 20 min. In one series of observations over a 2.5 h period following the restoration of light, a male's first feed lasted 13 min, the second occurred 105 min later on a new leaf and lasted 2 min, and the third feed began 3 min later on a new leaf and continued for 6 min. The female's first feed lasted 7 min whereupon she took 7 min to move to a new leaf and continued feeding for another 7 min. A third feed of 5 min occurred 70 min later, and a fourth lasting 4 min took place 35 min later.

Mating Behaviour

Pair Formation - Morabines lack tympana and have not been reported to stridulate so acoustical communication is unlikely. A male approached a female from as far as 7.5 cm. His head and antennae were lowered and pointed at her although sometimes pointing did not occur until he had nearly contacted her. The antennae were subparallel but became essentially parallel immediately before he mounted her. Males moved very slowly and took up to 10 min to traverse 4 cm. Olfactory and/or visual cues may be involved in pair formation as suggested by a female that began to open and close her ovipositor. A male 3 cm behind the female turned instantly and moved toward her until, after 1.5 min, he was oriented posterolaterally to her. Prior to this time he had shown no interest in her. Suddenly he lowered his head until it and the antennae pointed toward the female and 6 s later he mounted her.

Courtship Before Mounting - No premounting courtship was observed. A male would occasionally rock weakly just before mounting. At times a female would rock irregularly from side to side (ca. 3.5 cycles/s) for several seconds. Rocking could often be evoked by waving an object in front of a female.

Mounting, Courtship and Copulation - After mounting a female by jumping, a male positioned himself to face anteriorly and immediately tapped her prothorax in a rapid single burst (ca. 5 or 6 taps/0.5 s) with his alternating antennae. Females were never observed to resist males by vigorous jumping typical of acridid grasshoppers. Immediately upon being mounted or during antennal tapping the female lowered her hind femora so that they were horizontal and either parallel to her abdomen or somewhat spread. The male then lowered the distal third of his abdomen to probe the ventral side of the female's abdomen. The long cultriform portion of the subgenital plate was angled away from the female's abdomen and had no tactile role.

If the male was positioned too far forward, one of the following two sequences occurred:

1) The male alternated tapping each side of the female's thorax with his antennae (left antenna tapped the left side, right antenna the right side) as he simultaneously backed down her dorsum to insert his terminalia. Copulation time averaged 2.3 h (range 50 min to 3.5 h, n = 5).

2) Antennal tapping involved a single burst followed by one or two additional bursts each separated by one to several minutes, but copulation did not occur. The female remained immobile and the male either jumped or crawled off usually after 4 to 7 min. Riding on the back of a female for long periods of time was not observed. Once a male had dismounted, the female raised her femora to their normal position within 2 min.

It was not determined what cues from the female stimulated the male to tap her with his antennae continuously rather than sporadically. The only other female behaviours observed were uncommon and consisted of (1) a slight body vibration lasting only a few seconds and (2) moving her head down and up once, this sequence repeated about three times over a 3 min period. In both cases antennal tapping by the male was sporadic and copulation was unsuccessful.

The antennae of males appear to convey important tactile information since bursts of tapping occurred when contacting a food source and after mounting a female. Blackith and Goto (1974) noted that antennal tapping is typical of eumastacids. They found that the sensory fields on antennae of three morabine species consisted primarily of olfactory coeloconic sensilla which were protected by sclerotized masses surrounded by small numbers of trichoid sensilla. Trichoid sensilla are typically tactile receptors but the small number of them suggests that they would produce a weak signal from antennal tapping. Cursory observations of antennae of male and female *H. amiculi* with a scanning electron microscope revealed that the antennal sensilla were virtually identical to those of the eumastacid species studied by Blackith and Goto (1974). Coeloconic sensilla consisted primarily of stout rods and about 3% slender rods. The flat, ventral antennal surface had most and males had more proximally and distally than females. Up to 500 coeloconic sensilla could occur on the ventral surface of a segment. There were no unusual types or numbers of sensilla associated with antennal tapping. The large number of coeloconic sensilla indicated a strong dependence on olfactory cues.

Key (1976) noted that morabine species varied considerably in their internal anatomy and ecological characteristics and differed substantially from the norm for the Eumastacidae. It would be of interest to determine if other morabine species depart from the antennal tapping behaviour and the otherwise simple mating behaviour of *H. amiculi*.

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